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INSTITUTIONAL CAPACITY AND THE RESOLUTION OF A COMMONS DILEMMA

> This is the story of the fight to supply water for 250,000 people living in 82,000 homes in West Basin. It tells of efforts to find water for industries located here, so that thousands of workers might draw daily wages .... Tangible property, with an assessed value of over 250 million, had been developed and established, based on a water supply that was believed to be abundant and constant.
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> This is the story of depletion and contamination of that water supply. It is the story of reports, studies, investigations, committee meetings, mass meetings, parades, and elections, and also a story of opposing views, of tempers and temperament, of nonsensical argument. Finally, it is a story of success, of community cooperation, of mutual helpfulness, and of buried antagonisms. (Fossette, 1950, p. i)

West Basin is an underground water basin located adjacent to the Pacific Coast in Los Angeles County, California. It is the last of several interconnected groundwater basins underlying the south coastal plain. The success of the West Basin water producers in overcoming problems of depletion and contamination of the water resource makes this case relevant for those interested both in water resource management strategies and in more general questions concerning the resolution of commons problems.

As an example of a solution to a commons dilemma situation, not only are the institutional arrangements used in West Basin relevant to a broad class of problems but propositions derived from the theory of commons dilemma situations can be examined for their empirical relevance in this natural setting. Commons dilemmas arise from the joint use of a common-pool resource. A common-pool resource provides a finite flow of separable "use-units" over time. Multiple individuals can use a common-pool resource system simultaneously, but each person's consumption subtracts the amount consumed from the quantity available to others.[1]

Not every common-pool resource will necessarily produce a commons dilemma. A commons dilemma is characterized by the overuse, erosion, and deterioration of the resource's ability to continue to provide the valued "use-units." Whether or not a commons dilemma arises in a particular case of a common-pool resource depends upon the behavior or users, which in turn depends upon the structure of their situation and the incentives they face.

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Although the theory of commons dilemma situations is incomplete, several scholars have developed dynamic models that predict stable, long-term cooperative solutions (Lewis & Cowens, 1983) or the possibility of long-term cooperative equilibria (Axelrod, 1981; Taylor, 1977; Hardin, 1982). Others have presumed the principal--perhaps the only--hope for resolution of the commons dilemma and the preservation of the common resource is the coercive intervention of an external regulator (Carruthers & Stoner, 1981). Still others have concerned themselves with the possibilities for "privatizing" the commons by establishing separable and transferable property rights to the commons (Sinn, 1984; Welch, 1983; Anderson & Hill, 1977).

The West Basin case is noteworthy because the actions taken to preserve the commons were primarily designed by the water producers themselves, rather than being imposed on them by a state or national government. Yet in West Basin, strictly private action was not the case either. Public institutions and officials were involved throughout the process of resolution. The ability to use, create, and alter public institutions was critical to the formulation and implementation of the actions agreed upon by the local producers. Thus, resolution to this case by a mixture of private and public institutional arrangements constitutes a promising "middle ground" for the resolution of commons problems.

In this paper we consider the process of resolution of a commons dilemma in dynamic situations involving commons-sharing arrangements without an externally imposed solution, and we give particular attention to a model presented by Lewis and Cowens (1982) and to the conditions necessary to their result of a cooperative private arrangement, privately enforced. A different set permits a variety of processes to resolve a commons dilemma, one of which is illustrated in West Basin. Throughout this presentation, it is our purpose to build upon and contribute to the work of those scholars who have sought means other than an externally-coerced solution to such frequent, difficult, and variegated problems.

Conditions for the Resolution of a Commons Dilemma

At least two ways exist for resolving a commons dilemma in the absence of an externally imposed resolution. One way, which has already been explored in the literature, involves not only the absence of a coercive external regulator but the absence of any public institutions whatever. This approach relies entirely on voluntary, independent decisions made by the participants. Another way, which we propose, allows public institutions to facilitate voluntary agreements.

Resolution Without Institutions

The private "resolution without institutions" approach is presented in an important dynamic model by Lewis and Cowens (1983). They model the joint use of an ocean fishery by a group who harvest fish in each time period. Lewis and Cowens attempt to account for cooperative behavior in a commons dilemma in the absence of an imposed solution or external regulation. They search for conditions under which "users may be able to construct a cooperative scheme for conserving the resource that is self-policing," with enforcement by "the threat of retaliation by others" (1983, p. 2). Their conclusion is fundamentally different from that derived from static models. Lewis and Cowens predict an indefinitely extended cooperative equilibrium in the joint use of an open-access fishery. All participants monitor the behavior of rivals and harvest at an efficient rate (for the commons) as long as each observes the others doing so.

In light of their optimistic predictions for the resolution of the commons dilemma, and given their purpose in deriving such a resolution without the involvement of institutions, it is important to examine in some detail the assumptions underlying the Lewis and Cowens's model. Lewis and Cowens's outcome rests upon five necessary conditions. Each of the five conditions--information, communication, symmetry, enforcement, and monitoring--has been widely discussed by scholars concerned with the resolution of commons dilemma situations. For scholars interested in understanding how individuals cope with continuing, long-term commons dilemmas, the particular assumptions made about each of these conditions by Lewis and Cowens are hard to accept. Their assumptions are logical fictions necessary to drive through a proof. One might simply reject them all as unrealistic. We have taken a different approach.

We view each of these five conditions as *variables* that may take on *values* progressively approximating the conditions present in Lewis and Cowens's model. We then asked what type of institutional arrangements might enhance the possibility that this variable would approach a high value in the same direction as the assumption made by Lewis and Cowens. Our focus is on the question: Under what institutional arrangements would the value of this variable tend to approach that posited by Lewis and Cowens.

The Information Condition. Lewis and Cowens presume, as do most formal theorists, that participants have complete information about the structure of the situation they face. Participants are presumed to have information concerning the resource they are using and their own and others' use. They know the capacity and growth rate of the common resource, and thus are able to take future depletion effects into account in assessing the present value of cooperative and noncooperative strategies. Participants know the safe yield of the resource, the total amount of fish harvested by users in each time period, and make comparisons between the two. Therefore, they know if even a single user increases his or her harvest. Participants also know the total number of users, and the amount by which other users would increase their harvest if all defect. Thus, they can calculate the depletion effects of joint noncooperation.

Complete information is necessary in a model that excludes the consideration of institutions. In the absence of an information *source*, one must presume that participants already hold all knowledge necessary to their calculations, learning is not needed. Assuming complete information in a dynamic model places participants in a post-learning mode. They begin their participation in the use of the commons already comprehending all that is important to their decisionmaking.

The Communication Condition. Lewis and Cowens abstract from problems of communication among users by assuming that communication is immediate, undistorted, and costless. Information is shared by all because it is held by each. Threats of retaliation are understood by all because all users are assumed to be identical, facing identical strategic situations resulting from identical amounts of use. This interaction of the information condition discussed above with the symmetry condition discussed below renders communication among users unnecessary, which is the same as assuming perfect and costless communication. Lewis and Cowens note this in their discussion of the effect of the number of harvesters by acknowledging that an increase in the number of participants is usually associated with increased negotiation and monitoring costs (1983, p. 15).

The Symmetry Condition. Lewis and Cowens assume that all users are identical and there is perfect symmetry in use and in benefits from use.

The result, an indefinitely extended cooperative equilibrium, is conditioned on the assumption that each user consumes 1/nth of the present yield of the resource, each user maximizes the same utility function, and each user harvests the same amount from the resource and derives the same utility from that harvest. This condition (1) allows participants to take one another's actions into account and recognize what will succeed in deterring defections and (2) removes from the analysis potentially thorny problems of "fairness" that may arise in the development of a resolution of a commons dilemma that involves unequal division of the commons. This symmetry condition drives the model's private enforcement mechanism a long way: the shared understanding of participants that *all* will cooperate or *all* will defect is premised on the condition that all are alike in use of the commons and benefits derived therefrom.

The Enforcement Condition--Deterrence. Lewis and Cowens's harvesters enforce their commons-sharing arrangement by individually adapting to a deterrent strategy. The strategy is to restrain one's harvest at the cooperative level unless and until an excessive total harvest is detected. If anyone defects, the best reply that all of the other participants can make is to pursue noncooperative exploitation of the fishery for *all* subsequent time periods. The deterrent threat is not "tit for tat" but "defect forever if anyone defects once." This strategy is adopted by each of the identical harvesters and satisfies Selten' (1975) perfectness property as the optimal response of all possible histories of play.

The deterrent strategy is what makes the present value of restraint greater than the present value of defection. The recognition that any defection will destroy forever the common resource, keeps one from defecting, as long as future harvests are sufficiently weighted relative to the present harvests.

The Monitoring Condition. One condition that keeps Lewis and Cowens's fish harvesters from a situation in which some retaliate while others do not is the presumption of perfect and costless monitoring. Each harvester monitors the behavior of all others by monitoring the total fish harvest in each time period. Such monitoring is presumed to be without costs, and always correct.

The Cumulative Effect of the Conditions. Lewis and Cowens's model predicts an indefinitely extended cooperative arrangement, which is arrived at and enforced by the participants themselves. These conditions--and their configuration--are *necessary* conditions. All must be satisfied to reach and sustain the cooperative equilibrium.

Yet, each condition is unlikely to be obtained in a natural setting. Lewis and Cowens acknowledge, for instance, that the perfect and costless monitoring assumption is too strong to be satisfied in practice. If each of the conditions taken separately is unlikely to be met by an actual commons dilemma, certainly the odds of ever observing the confluence of all of them must be deemed exceedingly small.

The question then is how to treat these unrealistic conditions and the Lewis and Cowens model in analyzing the prospects for the resolution of a commons dilemma. A frequent stance taken by analysts is to ignore a model (or to criticize it) because its assumptions are unrealistic. An alternative stance is to disregard the assumptions and embrace the model by presuming that the predicted outcome is the most likely outcome in actual settings. Yet a third perspective, which we adopt, is to accept the model as a polar case showing the conditions necessary to an extreme sort of outcome--a purely private resolution privately enforced without institutions--and then to take the conditions it identifies as *variables*. These

variables have to take on extreme values to produce the original proof. These variables may exhibit a range of states or values in actual settings. Let us now examine how these five conditions could be reexamined using an institutional framework.

Resolution With Institutions

The Information Condition. If we relax the assumption that all participants with access to the commons already know everything about the resource and its users, then perhaps we should expect that participants will exploit the commons to an initial state of overuse *before* they become concerned with overuse. Detrimental effects of overuse may be the trigger for individuals who value the commons to begin to inquire about its capacity and its use by them and others.

The fact that users do not know all they need to know does not mean they are doomed to a dynamic of destruction. The availability of information can be viewed as a process. Information gathering can be initiated by the participants themselves. Before they find answers, we should expect they must discover the relevant questions. This may start with simple inquiries such as: Why is the water coming out of the well salty now? Or, why are we using more nets and catching fewer fish? When such a point is reached, the process can go in different ways.

If each individual user must undertake an investigation of the commons to discover personally all relevant information, the prospects may be dim indeed. If, on the other hand, a participant or group of participants can invoke an existing institutional arrangement to aid them in finding information about their problem, better prospects may arise. For policy analysts the question to ask may not be: Do all participants know what is going on? Rather, one should as: Is there some way for participants to find out what is going on? Can participants engage some mechanism for discovery about the causes of their losses? Is there a court system, an agency, or a foundation that might be able to inform the users or undertake an inquiry? Are cost-sharing arrangements available for such efforts?

The Communication Condition. If an information-gathering process is engaged by or on behalf of a subgroup of users, this will not translate into a resolution of a commons dilemma without dissemination to other users. This makes the identification of users and of the boundaries of the resource critical elements of information. In addition, a process of dissemination of information must exist or be developed.

The second dimension of communication is discourse among users about their common problem and possible joint strategies for resolution. If a solution is not externally imposed, and if we cannot expect each user to adopt the same strategy in isolation (as Lewis and Cowens posit), the choice and maintenance of commons-sharing arrangement requires communication among the users.

Such communication will neither be perfect nor costless. Not all users need be involved in the development of proposals or ideas about resolution. A self-selection process may even develop where those most immediately affected by overuse are most likely to seek out or create a forum for discussing possible resolutions. A trade association of fish harvesters or water producers, litigation among claimants to a resource, or some other arrangement, may make possible or require interaction among users. The point is that it may not be necessary to assume perfect and costless communication to obtain a resolution of a commons dilemma. If an imperfect forum provides some sharing of information and some interaction among users for the airing of possible resolutions, prospects will improve. The

greater the extent to which such a capacity is used, the greater the likelihood of resolution.

The Symmetry Condition. The symmetry condition raises the question of cost-sharing. Unless one is willing to assume total *a priori* information, (perfect and costless) communication, and costless enforcement monitoring, any resolution of the commons dilemma will involve costs, and thus the issue of cost allocation. The participants in Lewis and Cowens model bear the costs of harvest reduction and deterrence symmetrically since they are identical. In a symmetrical situation, a "prominent" solution (Schelling, 1963; also Hardin, 1982, p. 90) exists to the allocation problem; everyone bears 1/nth of the costs. Symmetry of interest in the use of the commons makes agreeing on a cost-sharing rule a trivial matter.

When the interests of joint users are asymmetric, this allocation decision is critically important. Allocation of costs must relate to the distribution of interests among the participants. The aggregation of benefits to participants from a particular cooperative scheme could exceed the aggregation of costs; yet participants still fail to bear the full costs because the *allocation* of costs to some exceeds their benefits. Hardin (1982, p. 92) argues that under conditions of asymmetry no abstract *a priori* cost-sharing rule can avoid conflicts when applied post hoc to an asymmetrical group whose numbers had not previously borne such costs. A cost-sharing rule must be developed and adopted for the particular case in question.

Lack of symmetry of interests is to be expected in actual settings. We believe it highly unlikely that each and every user of a joint facility other than a pure Samuelsonian public good will derive exactly the same benefit from its use and suffer exactly the same loss from its deterioration. If we are to have a theoretical treatment of an iterated commons dilemma capable of predicting anything other than absolute and inevitable destruction, we would have to acknowledge the institutional capacity of users to develop a cost-sharing rule suited to their case as a variable contributing to the structure of the situation and the prospects for resolution.

The Enforcement Condition. The Lewis and Cowens model implicitly makes a structural change in the interated Prisoners' Dilemma game that has been likened to the commons dilemma. Through their combination of conditions, they produce a situation where it is not possible to defect while all others cooperate. Nor would one cooperate while all others defect. Referring back to the original game structure, this operates as an elimination of the "temptation" and "sucker's" payoffs, leaving each player with a choice only of cooperating while all others cooperate (the second-best payoff) or defecting while all other defect (the third-best payoff). Under such a structure, cooperating dominates defecting. Such a situation yields an indefinitely extended equilibrium.

The question then arises, can such a structural change be made by users? The answer depends upon whether users are capable of making enforceable contracts that eliminate the "temptation" and "sucker" payoffs. A "contingent contract" accomplishes this and therefore can change a commons dilemma into a situation where cooperating dominates defecting.

In the context of an overused common resource, a contingent contract might begin with a proposed curtailment of use by all parties to a prescribed level. Such a proposal is submitted to each participant for ratification with a condition that the arrangement does not become binding upon that participant unless a stated proportion of the other participants also ratify. Participants can agree to such a curtailment, while being protected from being a "sucker," since there is no obligation to cooperate unless enough others do the same.

Once the sufficient number of participants have agreed to cooperate, the agreement takes effect. Like all contracts, it can be enforced by any party against any defector. Enforcement does not have to be private enforcement. The availability of institutions for the enforcement of contracts substitutes the cost of using such institutions for the cost of private enforcement and lowers the threshold of participation in enforcement from all users to as few as one. As monitoring approaches a sufficient degree of accuracy, the "temptation" payoff may be effectively eliminated, or at least reduced below the payoff from cooperating while all others cooperate. Institutional capacity for the making and enforcing contracts exists in many settings and the recognition of its availability may allow us to eliminate a number of problematic assumptions (e.g., identical users, complete information) necessary to the private-enforcement approach (see discussion by Hardin, 1982; Brubaker, 1975; & Guttman, 1978, of contingent contracting).

The Monitoring Condition. We cannot expect perfect and costless monitoring in a naturally occurring setting. The question is whether participants can structure a capacity that provides sufficient monitoring to deter participants from defecting and to sanction those who do. Every criminal act does not have to result in conviction and incarceration for law enforcement to work nor does every individual who exceeds the maximum allowable water use need to be caught to avoid the depletion of the common resource. The appointment of an outside monitor is also a feasible option in many institutional settings. An outside monitor displaces a considerable amount of the responsibility for enforcing the cooperative arrangement from the participants and can implement time-consuming means of monitoring that might not be feasible if joint users of the commons were the only monitors.

The Conditions as Variables. We have approached Lewis and Cowens's five conditions as a set of variables whose values may be affected by the institutional milieu within which a commons situation occurs. We have argued that the possibilities for cooperative commons-sharing arrangements are enhanced as the values of these five variables approach a sufficient level over time to shift the structure of incentives and constraints faced by joint users of the commons closer to those posited by Lewis and Cowens. But in the analysis of a long-term commons dilemma, it is not necessary to presume all five conditions must be met or the commons will be destroyed. The very fact that in most actual settings, commons dilemmas are iterated allows participants to evolve a solution through a variety of institutional arrangements. What conditions the resolution of a commons dilemma is the capacity to make such changes.

The general institutional arrangements that enhance the capability of participants to reach a particular solution include the institutional capacity to develop:

1. Information about the commons and use-patterns;
2. A forum for communication among those affected;
3. Cost-sharing formulae accepted by most participants as being equitable;
4. Enforceable, contingent contracts; and
5. Effective monitoring of use-patterns.

Individuals facing a commons dilemma situation in an institutional setting where they can develop the above institutions should be more likely to adopt a cooperative commons-sharing arrangement than individuals in an institutional milieu without such capabilities. In the case of the West Basin

groundwater commons dilemma, all of these capabilities were developed and used in the evolution of a program for the curtailment of use of the basin.

The West Basin Case and Institutional Capacity

In the West Basin of Southern California's Los Angeles County, joint users of a common resource have, over a number of years, formulated a solution to their iterated commons dilemma. Their solution is neither purely private nor an externally-imposed, coercive solution. It involves the development of capacities for communication, cost-sharing, and monitoring, and the use and adaptation of capacities for information provision, contracting and contract enforcement. It involves the interaction of private users, private institutions, and public institutions in a complex set of arrangements that generate a new rule configuration governing behavior in the joint use of the commons.

In a semiarid region such as the Los Angeles metropolitan area, economic development depends on the availability of a dependable water supply. Early economic development in the area was based almost exclusively on the use of groundwater. The "safe yields" of many of these basins were first exceeded in the 1930s. By the early 1940s, overdraft conditions were so severe in some basins that viability of the basins was threatened. Nonetheless, the water extracted from underground was more attractive in cost and quality than alternative sources. Water users continued to withdraw water and did so at an increasing rate as the area developed. West Basin, being adjacent to the Pacific Ocean and lowest in the series of basins, faced the most severe problems of overdraft and saltwater intrusion.

As individuals in the basin noticed water levels falling and word spread of saltwater intrusion, each pumper's incentive was to continue to increase pumping. Failure to do so would simply mean that one's desired water would be extracted by another user. Water levels steadily lowered, and saltwater intruded further and further along the coast. Unless the participants, or external authorities, restructured the situation faced by the water producers, they would jointly destroy a resource of considerable economic value.

Over approximately a 20-year period, the water producers of West Basin created a successful water management program (see Lipson, 1978, for the details of this development). This program involved developing various parts of the commons-sharing arrangement and then fitting them together. The steps toward the resolution of the problem included:

1. The creation of a voluntary association of water producers to share information available from a state water resources division about the boundaries and conditions of the south coastal plain basins, to provide a forum for discussion of the information and of possible alternatives to the present situation, and to relate activities occurring in different public arenas. The association was supported by voluntary dues from producers based on the amount of water each produced from the basin, with votes apportioned accordingly.
2. The use of the available court system for three principal purposes. First, through discovery and reference procedures, to ascertain reliable information on basin supply and use patterns, and to determine the identify of all other users in the basin. Second, to adjudicate rights based on use-patterns and the determined safe yield of the basin, which

rights were then secure unto the parties and could be worked into an agreement curtailing total use to the safe yield level. Three, to give force and effect to that agreement as an enforceable settlement provided that it was signed by at least 80 percent of users. The cost of the litigation was apportioned among the users based on their rights as determined in the agreement.

3. The establishment of an office of the state water resources agency as Watermaster to serve as a permanent monitor of use in the basin and compliance with the agreement. Two-thirds of the costs of the Watermaster service are assessed on these producers with rights to water and one-third is borne by the State of California.
4. The creation of a public water district covering the basin area to provide an alternative source of supply--i.e., to import sufficient fresh water into the area to make up the difference between groundwater extractions and total water use. Costs of the water district's operation and acquisition are borne by water users according to amount of use with minor reliance on the property tax.

The participants in the West Basin commons dilemma developed the institutional capacities necessary to their commons-sharing arrangement through their adaptation of existing capacities and their creation of new ones. The information condition, for instance, of each participant having complete information about the resource and use patterns was approximated by the adaptation of the data-collection practices of a state agency and the discovery and reference procedures of the court. The provision of information about individual users and the losses they were incurring and their willingness to explore alternatives occurred through the creation of the voluntary association.

The communication condition was approximated in a similar way. The creation of the association provided a forum for information dissemination and for the exploration of alternatives without the commitment by various association members. The use of litigation allowed dissemination of information and communication among users and eventual contingent commitment.

Cost-sharing arrangements were developed for each step in the resolution process. The use of proportionate cost-sharing began with the voluntary association. Dues were assessed based on the amount of groundwater extracted. In the court case, costs of investigation and litigation were matched to the benefit obtained in the judgement--i.e., the prescribed rights to water. The cost of monitoring compliance with the upper bounds of one's rights was again matched to rights, with a portion borne by the State of California. Citizens of the state have an interest that accurate information be gathered on groundwater conditions and that facilities be maintained that encourage solutions to commons dilemmas. The cost of providing an alternative source of supply was apportioned primarily to water *use*, rather than to production.

The use of contingent contracting to formulate an enforceable commons-sharing arrangement was explicit in the West Basin case. The plan for curtailment which emerged in the course of litigation was not effective unless 80 percent of the parties signed. The plan allowed those who did sign to move toward a cooperative resolution without being committed to a cooperative strategy that could result in a sucker's payoff. When 80 percent did sign, an interim agreement enforceable against signatories took

effect. After experience with the interim agreement, the final court judgement made it enforceable against *all* parties.

The capacity for effective monitoring of use patterns was developed out of the data collection function performed by the state's water resources division as fact-finding referee in the litigation of the West Basin case. Having formed a history of groundwater production in the basin, and having participated in the identification of all water producers in the basin, the agency was significantly better positioned to perform an ongoing monitoring of individuals' extractions than the individuals were to perform that function with respect to one another. So the agency was, in essence, "hired" as Watermaster to be paid by the parties and the state to monitor compliance with the curtailment agreement (see California, State of, annual reports for a detailed identification of exactly how much is pumped by each producer each year).

By the close of the process of development of the commons-sharing arrangement, West Basin water producers had put in place and used all of the elements of institutional capacity discussed above--information, communication, cost-sharing, contingent contracting, and monitoring. Through these measures, participants had fundamentally changed the rules structuring their situation in such a way that a cooperative response was more rational than a noncooperative response.

The development of a resolution of the commons dilemma is part of the West Basin story. From the standpoint of theoretical work and the analysis of commons dilemma situations, it is the most important part. But for the application of analytical work to actual settings, an equally important question is whether the commons-sharing arrangement "worked," in the sense of producing the intended results.

Considerable data exist on the historical use-patterns in West Basin and on the water quantity and quality conditions of the Basin. These data extend from approximately 25 years before the initiation of the basin-management programs to 30 years thereafter. We have examined this data series using least-squares regression techniques and ARIMA time-series analysis (Blomquist & Ostrom, forthcoming). The results of this testing indicate that aggregate extractions from the Basin have been curtailed to the safe yield of the basin and saltwater intrusion has not further undermined basin water quality. Confidence levels are sufficiently strong to support the conclusion that the basin-management programs developed for West Basin have indeed produced their intended results.

NOTES

[1]Thus, a commons is not a pure private good, as it is capable of use by more than one user at a time, and it is not a pure public good in the Samuelsonian sense of nonsubtractability, as a commons is a finite resource or facility that is susceptible to problems of crowding or overuse (see, for example, Ostrom & Ostrom, 1977). Nonetheless, the behavior of participants sharing a commons may be rather similar to the behavior of members of a group attempting to provide themselves with a public good.

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